

Epidemiology of moderate-to-severe penetrating versus closed traumatic brain injury in the Iraq and Afghanistan wars

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BACKGROUND:	US combat operations in Iraq and Afghanistan have resulted in a greater proportion of service members with head and neck wounds caused by explosions compared with that of previous wars. Although penetrating traumatic brain injury (TBI) is frequently associated with these wounds, the epidemiology of penetrating TBI from these conflicts has not been well described.
METHODS:	The Joint Theater Trauma Registry was queried for January 2003 through December 2010 to identify all patients with moderate-to-severe brain injury with a maximum Abbreviated Injury Scale (AIS) score of the head of 3 or greater and a diagnosis of penetrating or closed TBI in accordance with the Department of Defense Traumatic Brain Injury Surveillance definition. The epidemiology of these injuries was examined, including demographics, TBI severity, overall injury severity, and surgical interventions provided.
RESULTS:	A total of 1,255 TBI patients (774 penetrating, 481 closed) meeting criteria were identified. Penetrating brain injuries were more severe, more likely to be battle related, and less likely to be isolated injuries than a group of moderate-to-severe closed TBIs within the same range of anatomic injury severity. During the 5-year period of the Iraq war with the largest numbers of TBIs (2004–2008), the numbers of penetrating TBIs exceeded closed TBIs by a ratio of 2:1. During the 3-year period of the Afghanistan war with the greatest numbers of TBIs (2008–2010), the ratio of penetrating to closed TBIs was substantially lower, approximately 1.3:1.
CONCLUSION:	This study represents the first comprehensive report on the epidemiology of moderate-to-severe penetrating and closed TBIs resulting from the wars in Iraq and Afghanistan using Joint Theater Trauma Registry data. With the maturing theater of conflicts, penetrating TBIs were substantially less predominant compared with closed TBIs. While this finding may reflect changes in the use of protective measures and tactics or improvements in diagnosis of closed TBIs, additional research is needed to identify the reason for this shift and the subsequent effect on outcome after combat-related TBIs. (<i>J Trauma Acute Care Surg.</i> 2012;73: S496–S502. Copyright © 2012 by Lippincott Williams & Wilkins)
LEVEL OF EVIDENCE:	Epidemiologic study, level III.
KEY WORDS:	Traumatic and penetrating brain injury; military; epidemiology; Operation Enduring Freedom/Iraqi Freedom; Operation New Dawn.

The US combat operations in Iraq and Afghanistan have resulted in a greater proportion of service members with wounds to the head and neck compared with that of previous wars.¹ Because nearly 80% of these injuries are from explosions and 20% from gunshot wounds,^{1,2} penetrating traumatic brain injury (TBI) is often associated with these wounds. However, the epidemiology of penetrating TBI from these conflicts has not been well described. US Department of Defense (DOD) TBI Surveillance³ reports the numbers of

penetrating TBIs among service members but does not separate those from the wars. One study that described TBI patients at selected Level 5 military medical treatment facilities (MTFs)⁴ likely underestimated the number of penetrating TBIs by excluding those who did not survive to reach Level 5 or who were treated elsewhere. The results of studies of the Navy and Marines only^{5,6} may not be generalizable to all service members hospitalized with penetrating TBI from Operation Iraqi Freedom (OIF) and Operation New Dawn (OND) in Iraq and Operation Enduring Freedom (OEF) in Afghanistan.

Inpatient hospitalizations of US military personnel with penetrating TBI who were medically evacuated have been reported, but information about TBI severity and mechanism of injury were lacking.⁷ Studies using data from the Joint Theater Trauma Registry (JTTR)⁸ identified penetrating TBIs based on the primary body injury type (penetrating, explosion/blast, blunt).^{9,10} Wade (in Santiago et al.¹¹) also reported the number of TBIs caused by a penetrating mechanism. Because TBI patients may have been injured by more than one mechanism, the primary body injury type may not reflect the true cause of the TBI or the TBI diagnosis. A study of service members with isolated severe TBI using JTTR data likely correctly identified penetrating versus closed TBIs;¹² however, the exclusion of patients with multiple injuries and those with TBIs caused by explosions limits the generalizability of those findings.

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A better understanding of the epidemiology of penetrating TBI from the Iraq and Afghanistan conflicts is needed to characterize this unique group of injured service members. The objective of this study was to describe the epidemiology of moderate-to-severe penetrating TBI compared with closed TBI identified from the JTTR.

PATIENTS AND METHODS

This study was conducted under a protocol approved by the US Army Medical Research and Materiel Command Institutional Review Board and in accordance with the approved protocol. Data were from the JTTR.⁸ US service members 18 years or older admitted to a North Atlantic Treaty Organization Role 3 MTF¹³ with a moderate-to-severe penetrating or closed brain injury from 2003 through 2010 were eligible for inclusion. Potential cases were further identified based on (a) the Abbreviated Injury Scale (AIS) score¹⁴ for the head and (b) International Classification of Diseases—9th Rev.—Clinical Modification (ICD-9-CM) diagnosis code(s)¹⁵ for TBI assigned at a Role 3 or Level 4 facility. Because we were interested in more severe injuries and to compare penetrating injuries, which tend to be more severe, with closed head injuries, we limited our analyses to patients with a maximum AIS score of the head of 3 (serious) or greater (i.e., more severe).

Patients meeting the previously mentioned criteria were then confirmed as having a TBI diagnosis according to the DOD TBI Surveillance definition¹⁶ (Appendix) and categorized as penetrating versus closed (mild, moderate, or severe) by applying the DoD surveillance classification (Athena Kendall-Robbins, Defense and Veterans Brain Injury Center, personal communication, August 5, 2010). Penetrating TBI is defined as open head injury (skull fracture) with mention of intracranial injury; moderate TBI is defined as (a) closed head injury (skull fracture) without mention of intracranial injury and with loss of consciousness (LOC) of 1 hour to 24 hours; (b) closed head injury (skull fracture) with mention of intracranial injury and LOC for 24 hours or less, of unspecified duration, or with concussion (unspecified); or (c) “concussion” with LOC for longer than 30 minutes to 24 hours. To facilitate categorization, we used diagnosis codes assigned at both Role 3 and Level 4 MTFs. Because some patients had multiple codes assigned at Role 3 and/or Level 4, we classified cases using these codes according to a hierarchy starting with penetrating and proceeding from severe through mild closed TBI. For each level of the hierarchy, a case was assigned to the category (e.g., penetrating TBI) if it had at least one ICD-9-CM diagnosis code for that type of TBI assigned at a Role 3 facility; if not, the case was included if it had a code for that type of TBI assigned at a Level 4 facility. Mild TBIs and those that could not be classified were excluded from subsequent analyses.

Variables included age at injury, sex, branch of military service, military operation (OEF vs. OIF/OND), and year of injury. Injuries were characterized by the setting (battle/nonbattle), mechanism of injury (explosive device, gunshot wound, motor vehicle crash, or other), primary body injury type (penetrating, explosion/blast, blunt, or other/unknown), and Injury Severity

Score (ISS) (categorized as 0–15 [least severe], 16–25, 26–55, and >55 [most severe]). Isolated TBI was defined as having no other trauma-related ICD-9-CM diagnosis codes. Head injury severity was based on maximum AIS score for the head. The ICD-9-CM procedure code categories for neurosurgical interventions are listed in the Appendix.

Statistical analysis was performed using SAS version 9.2 (Statistical Analysis Software, Cary, NC). Percentages were calculated and distributions for penetrating versus closed TBI were compared using the χ^2 statistic or Fisher’s exact test when cell counts were small.

RESULTS

After exclusion of 456 cases with mild TBI and 133 that could not be classified as TBIs, 1,255 cases (774 penetrating and 481 closed) were available for analysis. Unclassified cases did not differ from the study population with regard to age and sex ($p > 0.05$), but they had less severe head injuries and overall injuries than the study population based on maximum AIS score of the head ($p < 0.0001$) and ISS category ($p = 0.006$), respectively.

As shown in Table 1, comparison of TBI type (penetrating vs. closed) according to our ICD-9-CM diagnosis code-based definition with the variable “primary body injury type” from the JTTR revealed substantial differences. Among the cases categorized as penetrating TBIs based on diagnosis codes, 71.5% were also classified as “penetrating” according to primary body injury type. Among those categorized as closed TBIs based on diagnosis codes, 42.2% were misclassified as “penetrating” using the primary body injury type variable. Because of these differences, no further analyses by “primary body injury type” were performed.

Table 2 shows the characteristics of the study population by TBI type (penetrating vs. closed). Type of TBI did not differ by age group ($p > 0.05$). Both penetrating and closed TBIs tended to occur more frequently among men (99.1% and 97.7%, respectively) than women ($p = 0.05$). Nearly three fourths of both penetrating and closed TBIs occurred among Army soldiers and approximately 20% among Marines ($p = 0.03$). Greater percentages of both penetrating (80.9%) and

TABLE 1. Comparison of TBI Type According to ICD-9-CM Diagnosis Codes Versus Primary Body Injury Type, JTTR, 2003 to 2010

Primary Body Injury Type	Type of Moderate-to-Severe TBI Based on ICD-9-CM Diagnosis Codes	
	Penetrating (n = 774), n (%) [*]	Closed (n = 481), n (%)
Penetrating	553 (71.5)	203 (42.2)
Explosion/blast	180 (23.3)	74 (15.4)
Blunt	38 (4.9)	199 (41.4)
Other/unknown	3 (0.4)	5 (1.0)

^{*}Some percentages do not add to 100 owing to rounding off.

TABLE 2. Characteristics of the Study Population by Moderate-to-Severe Penetrating Versus Closed TBI, JTTR, 2003 to 2010

Characteristic	Type of Moderate-to-Severe TBI			χ^2 <i>p</i>
	Penetrating (n = 774), n (%) [*]	Closed (n = 481), n (%)	Total (n = 1,255), n (%)	
Age at injury [†]				
18–24	438 (56.7)	249 (51.9)	687 (54.8)	0.13
25–34	251 (32.5)	163 (34.0)	414 (33.0)	
≥35	84 (10.9)	68 (14.2)	152 (12.1)	
Sex				
Male	767 (99.1)	470 (97.7)	1237 (98.6)	0.05
Female	7 (0.9)	11 (2.3)	18 (1.4)	
Branch of service				
Army	567 (73.3)	348 (72.4)	915 (72.9)	0.009
Marines	175 (22.6)	94 (19.5)	269 (21.4)	
Air Force	15 (1.9)	12 (2.5)	27 (2.2)	
Navy	17 (2.2)	27 (5.6)	44 (3.5)	
Military operation				
OEF	148 (19.1)	128 (26.6)	276 (22.0)	<0.002
OIF	626 (80.9)	353 (73.4)	979 (78.0)	

*Some percentages do not add to 100 owing to rounding off.

[†]Two cases with missing age were excluded.

closed TBIs (73.4%) occurred during OIF/OND compared with OEF ($p = 0.002$).

As shown in Table 3, penetrating TBIs were more likely than closed TBIs to be battle related (94.3% vs. 67.6%, respectively; $p < 0.0001$) and more severe, with a greater percentage in the critical range of maximum AIS score of the head (39.7% vs. 15.8%, respectively; $p < 0.0001$). Although greater than 90% of both types of TBIs had comorbid body injuries, penetrating TBIs were less likely to be isolated injuries than were closed TBIs (6.7% vs. 2.9%; $p < 0.003$). Overall injury severity was greater among patients with penetrating TBIs; specifically, 13.6% of patients with penetrating TBIs were in the lowest category of ISS (0–15) compared with 28.7% of those with closed TBIs ($p < 0.0001$). Patients with penetrating brain injury were more likely to have been injured by an explosive device (69.8% vs. 57.0%, respectively) or gunshot wound (26.6% vs. 6.7%, respectively) compared with closed TBI patients, whereas those with closed TBI were more likely to have been injured in a motor vehicle crash or by another nonpenetrating mechanism ($p < 0.001$). With regard to treatment, more than half of those with penetrating TBI (51.8%) had at least one neurosurgical intervention compared with 21.2% of those with closed TBI ($p < 0.0001$). Penetrating TBI patients were more likely than those with closed TBI to have had any of the interventions including intracranial pressure (ICP) monitoring (32.2% vs. 16.0% respectively, $p < 0.0001$) and craniectomy (24.0% vs. 5.2%, respectively; $p < 0.0001$).

Separate analysis of men versus the small number of women ($n = 18$) (data not shown) revealed that 9 (81.8%) of the 11 women with closed TBI were injured in a nonbattle setting, compared with 31.3% of the men; nearly all penetrating TBIs occurred in a battle setting regardless of sex (7 of 7 women and 94.3% of men, respectively; $p < 0.0001$). Explosive devices were associated with 7 (38.9%) of 18 of the

TBIs among women and 65.2% among men, whereas motor vehicle crashes were associated with 6 (33.3%) of 18 TBIs among women and 7.0% among men ($p = 0.0004$).

The figures show the distributions of penetrating and closed TBIs by year and conflict. For OIF/OND (Fig. 1), the numbers of both types of TBI were greatest from 2004 through 2007 and decreased steadily from 2008 through 2010. During the 5-year period of OIF/OND with the largest numbers of TBIs (2004–2008), penetrating TBIs exceeded closed TBIs by a ratio of approximately 2:1. For OEF (Fig. 2), the numbers of both types of TBIs remained relatively small until 2008 when they increased and then rose steadily through 2010. During the 3-year period of OEF with the greatest numbers of TBIs (2008–2010), penetrating TBIs exceeded closed TBIs by a ratio of approximately 1.3:1.

DISCUSSION

This study is the first comprehensive epidemiologic report describing penetrating brain injury from the wars in Iraq and Afghanistan identified in the JTTR. The 774 penetrating TBIs in our study were more severe, more likely to be battle related, and less likely to be isolated injuries than moderate-to-severe closed TBIs within the same broad range of anatomic injury severity. Strengths of the study included the identification of penetrating versus closed TBIs based on diagnosis rather than primary mechanism of bodily injury and inclusion of patients from all four services.

Compared with earlier conflicts, more injured service members with critical injuries survived to reach treatment at a Role 3 MTF,¹⁷ thereby becoming eligible for inclusion in this study. Damage-control surgery by forward surgical teams,¹⁸ improvements in medical evacuation,¹⁸ and aggressive neurosurgical treatment^{4,18–21} likely contributed to the initial survival

TABLE 3. Injury Characteristics of the Study Population by Moderate-to-Severe Penetrating Versus Closed TBI, JTTR, 2003–2010

Characteristic	Type of Moderate-to-Severe TBI (TBI)			χ^2 p
	Penetrating (n = 774), n (%) [*]	Closed (n = 481), n (%)	Total (n = 1,255), n (%)	
Setting				
Battle	730 (94.3)	325 (67.6)	1055 (84.1)	<0.0001
Nonbattle	43 (5.6)	155 (32.2)	198 (15.8)	
Unknown	1 (0.1)	1 (0.2)	2 (0.2)	
Head injury severity (maximum AIS score of the head)				
3 (serious)	180 (23.3)	276 (57.4)	456 (36.3)	<0.0001
4 (severe)	262 (33.8)	126 (26.2)	388 (30.9)	
5 (critical)	307 (39.7)	76 (15.8)	383 (30.5)	
6 (unsurvivable)	25 (3.2)	3 (0.6)	28 (2.2)	
Isolated TBI†	52 (6.7)	14 (2.9)	66 (5.3)	<0.003
ISS				
0–15	105 (13.6)	138 (28.7)	243 (19.4)	<0.0001
16–25	296 (38.2)	150 (31.2)	446 (35.6)	
26–55	342 (44.2)	182 (37.8)	524 (41.8)	
>55	31 (4.0)	11 (2.3)	42 (3.4)	
Primary mechanism of body injury‡				
Explosive device	540 (69.8)	274 (57.0)	814 (64.9)	<0.0001
Gunshot wound	206 (26.6)	32 (6.7)	238 (19.0)	
Motor vehicle crash	9 (1.2)	84 (17.5)	93 (7.4)	
Other	18 (2.3)	89 (18.5)	107 (8.5)	
Unknown	1 (0.1)	2 (0.4)	3 (0.2)	
Surgical intervention§				
Any intervention	401 (51.8)	102 (21.2)	503 (40.1)	<0.0001
ICP monitoring	249 (32.2)	77 (16.0)	326 (26.0)	<0.0001
Craniotomy	167 (21.6)	30 (6.2)	197 (15.7)	<0.0001
Craniectomy	186 (24.0)	25 (5.2)	211 (16.8)	<0.0001
Skull debridement	110 (14.2)	8 (1.7)	118 (9.4)	<0.0001
Brain debridement	103 (13.3)	1 (0.2)	104 (8.3)	<0.0001
Brain lobectomy	36 (4.6)	1 (0.2)	37 (3.0)	<0.0001

^{*}Some percentages do not add to 100 owing to rounding off.

†TBI only; no other ICD-9-CM codes for injury.

‡Refers to the primary mechanism of all injury, not specific to the head.

§Based on ICD-9-CM procedure codes for neurosurgical interventions (Appendix).

of some patients who in earlier conflicts would have been deemed unsalvageable or would have died from inefficient delivery of care.

Our findings confirm previous reports of resurgence in the use of neurosurgical interventions, including decompressive craniectomy, which were not widely used in previous conflicts.⁴ Some studies have investigated the association of these interventions with mortality¹² or global outcomes,^{4,22} but further research on life expectancy and the factors associated with longer-term survival is warranted.

Our results are consistent with reports of a high proportion of TBIs in OEF and OIF caused by explosions.^{4–6} Penetrating TBIs from explosions can be caused by metal fragments, objects such as nails embedded within improvised explosive devices, or structural debris.²³ Modern Kevlar helmets provide better protection from penetrating brain injury than in previous conflicts,²⁴ but the face remains vulnerable.²⁵ Our findings related to mechanism are limited, however, because the JTTR included only primary mechanism of injury, which may differ

from the mechanism(s) that caused the TBI. Nevertheless, our finding that 69.8% of penetrating TBIs were caused by explosions is similar to that of Bell et al.⁴ who reported 71.5% caused by explosions among their sample of OIF inpatients. In OEF/OIF, explosions primarily caused by improvised explosive devices^{17,26} are the leading cause of combat-related injuries (74%–78%),^{1,2} followed by gunshot wounds (18%–20%).^{1,2} The proportion of explosion-related injuries in OEF/OIF is larger, and the proportion of gunshot wounds is smaller, compared with those of previous conflicts including the Vietnam War, during which 65% of injuries were caused by explosions and 35% from gunshot wounds.¹

The very small number of TBIs and the predominance of nonbattle versus battle injuries among women were expected because they constitute only 11% of the active duty population and have largely been excluded from direct action combat units.²⁷ The larger proportion of TBIs associated with motor vehicle crashes among women than men is also consistent with the greater involvement of women in noncombat

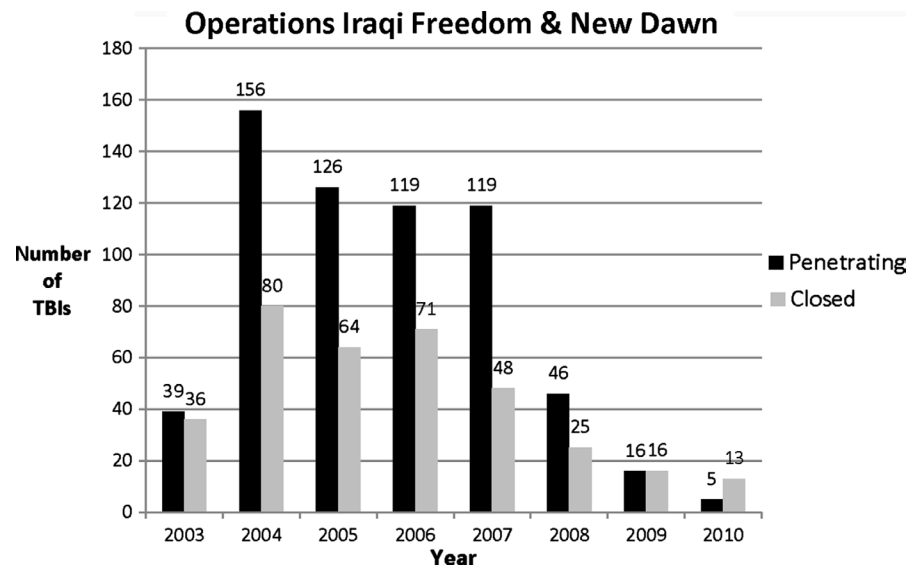


Figure 1. Moderate-to-severe penetrating and closed TBIs by year, OIF and OND, JTTR, 2003 to 2010.

support roles such as transportation. This pattern may change in the future as more women serve on the battlefield.

Studies of the longer-term outcomes of service members with penetrating brain injuries are needed to document the incidence and risk factors for neurocognitive decline, epilepsy, and other TBI-related conditions.²⁸ A previous study reported that 32% of participants with penetrating TBI from the Iran-Iraq War became epileptic during an average of 39.4 months of follow-up.²⁹ Similarly, 53% of participants in the Vietnam Head Injury Study (VHIS), a multiphase longitudinal study of Vietnam War veterans with penetrating TBI, developed epilepsy during 15-year follow-up.³⁰ Because penetrating brain injury typically results in focal lesions with identifiable long-term sequelae, follow-up studies of the OEF/OIF/OND population could add to the knowledge of the effects of TBI

gained from the VHIS³¹ and earlier research from the great wars of the 20th century.³² A comprehensive longitudinal study to evaluate the impact of injury characteristics, early management, surgical innovations, and rehabilitation on the longer-term outcomes of penetrating TBI is needed to inform improvements in both early and late treatment.

The higher numbers of both closed and penetrating TBIs during the early years of OIF compared with OEF may be caused by several factors. They include a larger number of deployed service members or “boots on the ground,”³³ a higher operational tempo, and a greater number and intensity of explosions in OIF, especially during the 15-month “surge.”³⁴ Increased use of protective transport, especially mine-resistant, ambush-protected vehicles known as MRAPs,³⁵ in Iraq after 2008 and reduced troop numbers and intensity of combat

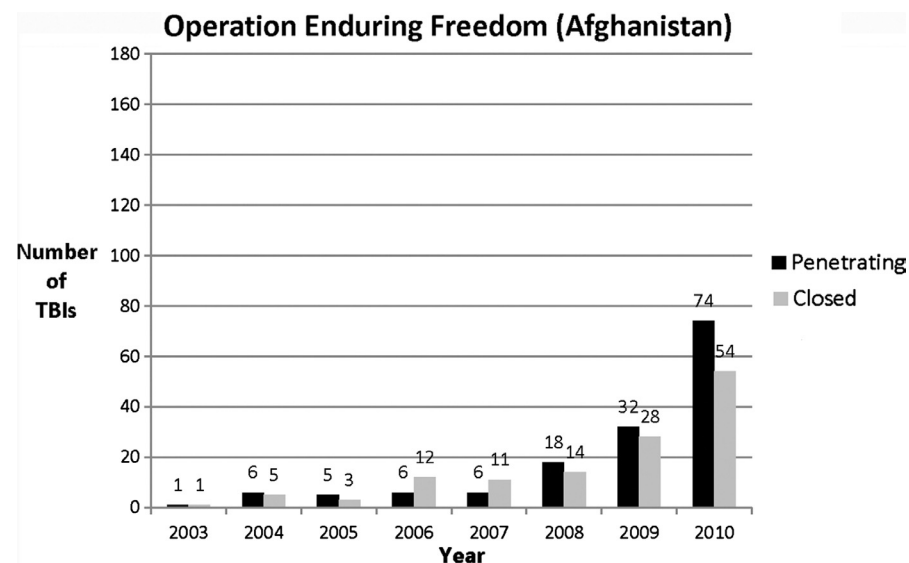


Figure 2. Moderate-to-severe penetrating and closed TBIs by year, OEF (Afghanistan), JTTR, 2003 to 2010.

leading up to the official end of OIF in 2010 likely contributed to decreased numbers of TBIs in OIF over time. Reasons for the relatively high ratio (2:1) of penetrating to closed TBIs during the years of OIF with the greatest numbers of TBIs (2004–2007) are unclear but may be related in part to increased risk of penetrating injuries from explosions owing to the lack of protective transport vehicles. In contrast, the steady increase in numbers of TBIs in OEF during the later years of the study is consistent with increasing troop levels³³ and operational tempo¹⁷ and a higher incidence of explosion as the mechanism of injury.¹ Reasons for the lower ratio (1.3:1) of penetrating to closed TBIs during the years of OEF with the greatest numbers of TBIs (2008–2010) relative to the comparable but earlier period during OIF are also unclear. Increased awareness among military medical personnel of the risk of closed TBI associated with exposure to explosions could have resulted in improved diagnosis of these injuries over time. The implementation of an in-theater clinical practice guideline³⁶ and establishment of a chain of responsibility for identification of these TBIs, which includes military leaders^{37,38} may also have contributed to an increase in the number of service members with a closed TBI diagnosis later in the wars. Finally, differences in the tactical requirements for dismounted battle in OEF¹⁷ compared with OIF also could have been a factor.

Our findings revealed that previous studies that classified penetrating and closed TBIs based on the primary body injury type listed in the JTTR may have misclassified as many as 30% of penetrating and 40% of closed TBI patients. Thus, previous reports of the incidence of penetrating TBI from OIF/OEF and OEF that used this classification^{10,11} may be inaccurate. Our use of ICD-9-CM diagnosis codes to categorize TBIs likely resulted in more accurate identification of penetrating versus closed TBIs based on the nature of the injury to the brain.

Our study has some limitations. First, the use of ICD-9-CM codes to identify penetrating versus closed TBIs, although more accurate than classification according to primary body injury type, may still have resulted in some errors in the identification and categorization of the patients in our study. Future studies of TBI outcomes using these data would benefit from detailed reviews of medical records and neuroimaging findings to confirm the nature and severity of the brain injuries. Second, we studied patients with the most severe penetrating and closed TBIs who reached a Role 3 MTF; however, the data on those who were killed in action or died of wounds were not available to us. Eastridge et al.³⁹ reported that 83% of those who died of wounds classified as nonsurvivable and 9% of those classified as potentially survivable died primarily as a result of TBI. Thus, the exclusion of service members with TBI who died before transport to a Role 3 MTF biases our findings toward survivors.

In conclusion, our study provides important information about the epidemiology of moderate-to-severe penetrating and closed TBI from the US combat operations in Iraq and Afghanistan. With the maturing theater of conflicts, closed TBIs, although still outnumbered by penetrating injuries, constitute a larger proportion of TBIs overall. Additional research is needed to identify the reasons for this shift and the subsequent effect on outcome after combat-related TBI.

APPENDIX. ICD-9-CM Diagnosis Code Categories

DOD TBI Surveillance Definition*

310.2 (postconcussion syndrome)
800.0x 800.9x (fracture of vault of skull)
801.0x 801.9x (fracture of base of skull)
803.0x 803.9x (other and unqualified skull fractures)
804.0x 804.9x (multiple fractures involving skull or face with other bones)
850.x (concussion)
851.0x 851.9x (cerebral laceration and contusion)
852.0x 852.5x (subarachnoid, subdural, and extradural hemorrhage, following injury)
853.0x 853.1x (other and unspecified intracranial hemorrhage following injury)
854.0x 854.1x (intracranial injury of other and unspecified nature)
907.0 (late effect of intracranial injury without skull or facial fracture)
950.1 950.3 (injury to optic chiasm/pathways or visual cortex)
959.01 (head injury, unspecified)

Neurosurgical procedures

ICP monitoring
1.02 ventriculopuncture through previously implanted catheter
1.10 ICP monitoring
1.16 intracranial oxygen monitoring
1.18 other diagnostic procedures on brain and cerebral meninges
1.26 insertion of catheter(s) into cranial cavity or tissue
2.2 ventriculostomy
Craniotomy
1.21 incision and drainage of cranial sinus
1.23 reopening of craniotomy site
1.24 other craniotomy
1.31 incision of cerebral meninges
1.39 other incision of brain
Craniectomy
1.25 other craniectomy
2.12 other repair of cerebral meninges
Brain lobectomy
1.53 lobectomy of the brain
Skull debridement
2.02 elevation of skull fracture fragments
Brain debridement
1.59 other excision or destruction of lesion or tissue of brain
2.92 repair of brain

*Source: Armed Forces Health Surveillance Center, 2012.

AUTHORSHIP

J.A.O. conducted the literature search and, with D.H., designed this study. J.J. performed the data analysis; J.A.O., D.G., and J.J. interpreted the data. J.A.O., D.G., E.B.S., J.G., M.J.P., and J.D. contributed to writing the manuscript, which J.A.O., E.B.S., and J.G. critically revised.

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DISCLOSURE

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